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Andrew B. Heckert

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UPPER TRIASSIC TETRAPODS FROM THE LUCERO UPLIFT, CENTRAL NEW MEXICO

ANDREW B. HECKERT
Department of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131-1116

Abstract—Six localities in the lower Chinle Group of central New Mexico yield a tetrapod fauna consisting of the diminutive metoposaurid cf. *Apachesaurus* sp., and indeterminate large metoposaurids (probably *Buettneria* sp.), the phytosaur *Rutiodon* sp., indeterminate phytosaurs, the aetosaurs *Desmatosuchus* sp. and cf. *Stagonolepis* sp., a probable theropod, and other, indeterminate archosaurs. Five of these localities are in the Bluewater Creek Formation, and yield all components of the Upper Triassic tetrapod fauna from the Lucero uplift (Lucero local fauna) except for an isolated scute of *Desmatosuchus* sp., recovered from the homotaxial San Pedro Arroyo Formation. Of the Bluewater Creek Formation tetrapods, the most complete specimen represents a large (4-m body length) phytosaur assigned to *Rutiodon* sp. and consists of a partial pelvis, an interclavicle, five articulated vertebrae, and numerous ribs. The remaining elements of this fauna closely resemble other faunas collected from the Bluewater Creek Formation. In particular, the abundance of metoposaurids and phytosaurs is similar to faunas in the Zuni Mountains in west-central New Mexico and the Blue Hills near St. Johns, Arizona. The presence of the aetosaur cf. *Stagonolepis* sp. and the phytosaur *Rutiodon* sp., both of which are index taxa of the Adamanian land-vertebrate faunachron, indicates a latest Carnian age for the Lucero local fauna, an age assignment consistent with that of the Bluewater Creek Formation elsewhere.

INTRODUCTION

The Upper Triassic paleontology of the Lucero uplift in central New Mexico (Fig. 1) has been relatively understudied compared to other Triassic outcrop belts in the state. In this paper I (1) outline the history of Triassic paleontological collections from the Lucero uplift; (2) briefly describe the stratigraphic context of tetrapod localities in the uplift; (3) systematically describe the Upper Triassic tetrapod fauna; and (4) comment on the significance of this fauna.

HISTORY OF STUDY

In spite of its proximity to both Albuquerque and Socorro, no substantial efforts to collect Upper Triassic vertebrates from the Lucero uplift were made prior to the late 1980s. This is almost certainly a result of a combination of the poor exposure and structural complexity that typifies Chinle Group outcrop distribution in the area. Case (1916) reported fragmentary Upper Triassic tetrapod fossils several km north of Carthage in Socorro County that confirmed a Late Triassic age for the red beds there, but made no systematic attempt to collect tetrapod fossils. Hunt et al. (1989) documented a limited fauna consisting of the aetosaur *Stagonolepis* (=*Calyptosuchus*) and undiagnostic phytosaur and metoposaur material from the Bluewater Creek Formation. Hunt and Lucas (1993a) summarized the known vertebrate fauna of the lower Chinle Group in the Lucero uplift, essentially reiterating the observations of Hunt et al. (1989). Lucas and Heckert (1994) identified a scute of the aetosaur *Desmatosuchus* from the San Pedro Arroyo Formation in the southern Lucero uplift.

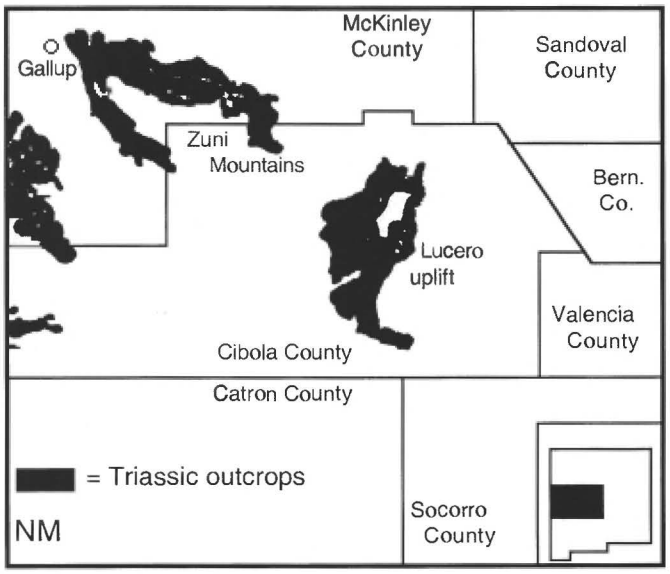

FIGURE 1. Outcrop distribution of Triassic strata in west-central New Mexico showing the position and large outcrop areas of the Lucero uplift. Modified from Stewart et al., 1972.

Following these reconnaissance efforts, the New Mexico Museum of Natural History and Science (NMMNH) initiated several collecting trips to the Lucero uplift in 1996 and 1997. Here, I document the results of these efforts, and provide a comprehensive faunal list of the lower Chinle Group in the Lucero uplift that completely indexes all material collected there by parties of the NMMNH. I do this in part because existing documentation of these collections was never intended to be complete, but also because numerous nomenclatural changes have occurred since 1989, so that many of the taxonomic assignments made by Hunt et al. (1989) are out of date.

STRATIGRAPHY

All Upper Triassic strata in the Lucero uplift pertain to the Chinle Group as defined by Lucas (1993). Chinle Group strata in the Lucero uplift consist of, in ascending order, the "mottled strata" and the Shinarump, Bluewater Creek/San Pedro Arroyo, Petrified Forest, Owl Rock, and Rock Point formations (Lucas and Heckert, 1994) (Fig. 2). South of the Rio Salado, strata of the San Pedro Arroyo Formation laterally replace Bluewater Creek Formation strata (Lucas and Heckert, 1994). Throughout the Lucero uplift the Sonsela Member is the lowest exposed member of the Petrified Forest Formation, as the underlying Blue Mesa Member appears to be absent due to erosion during development of the Tr-4 unconformity of Lucas (1993). Middle Jurassic (Entrada Formation) to Neogene (Santa Fe Group) strata disconformably overlie Upper Triassic Chinle Group rocks in the Lucero uplift. Stratigraphic relationships of Chinle Group units in the Lucero uplift are difficult to ascertain because of the low relief and complex structure throughout the uplift, as well as a lack of persistent bench-forming units within the Chinle. Numerous ledges, benches, and ridges of Sonsela or Shinarump strata are exposed, but reinforce areas of such low relief that it is almost impossible to measure complete stratigraphic sections of formation-rank units. The sole exception is the Rio Salado section described by Lucas and Heckert (1994).

Lucas and Heckert (1994) conducted detailed studies of the lithostratigraphy of the Triassic strata in the Lucero uplift, reaching several conclusions reiterated here. In particular, they noted that: (1) the Bluewater Creek Formation is replaced laterally by the San Pedro Arroyo Formation south of the Rio Salado; (2) the Blue Mesa Member of the Petrified Forest Formation is absent in the Lucero uplift; and (3) the McGaffey Member of the Bluewater Creek Formation extends eastward from the Zuni Mountains at least as far as the northern Lucero

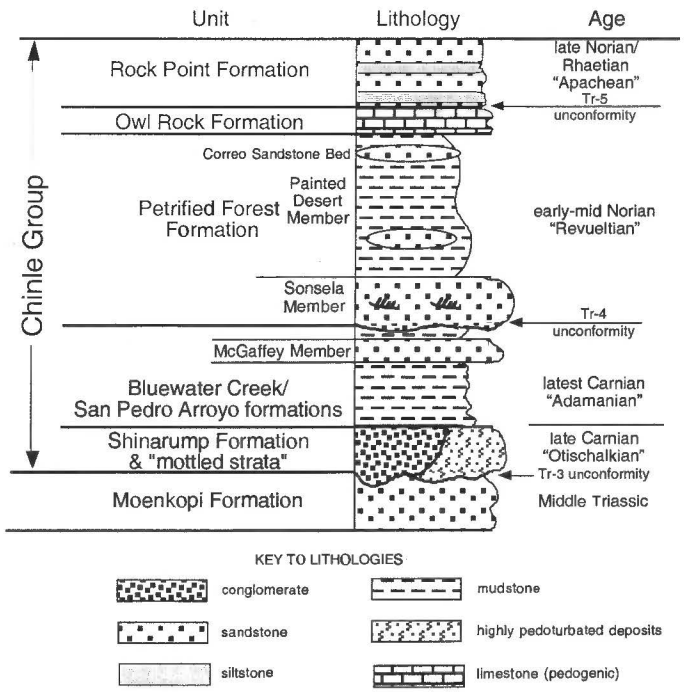

FIGURE 2. Generalized Triassic stratigraphic section in the Lucero uplift. Stratigraphic interpretations follow Lucas and Heckert (1994).

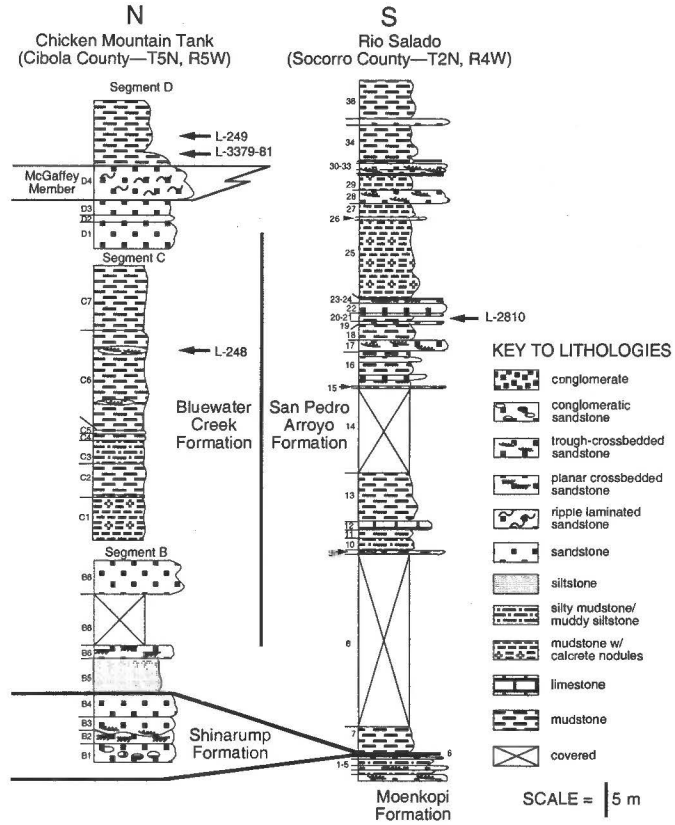

FIGURE 3. Stratigraphic distribution of lower Chinle Group tetrapod localities in the Lucero uplift. All locality numbers are for NMMNH localities.

uplift. To date, all Triassic tetrapod fossil localities in the Lucero uplift are from the lower Chinle Group, and most are concentrated in the middle to upper Bluewater Creek Formation, although NMMNH locality L-2810 is in the San Pedro Arroyo Formation (Fig. 3).

All of the Bluewater Creek Formation localities occur in red-bed deposits of reddish brown to reddish purple, bentonitic mudstones with thin, intraformational conglomerates and occasional calcrete nodule horizons (Fig. 3). Heckert and Lucas (1996) and Heckert (1997) identified these as the most common lithofacies of that unit. The stratigraphic distribution of the localities spans much of the stratigraphic thickness of the Bluewater Creek Formation in the uplift (Fig. 3). The single tetrapod specimen obtained from the San Pedro Arroyo Formation, a scute of the aetosaur *Desmatosuchus* sp., was obtained from a channel sandstone and conglomerate sheet in the middle of the formation (Lucas and Heckert, 1994, fig. 9; Fig. 3).

The Bluewater Creek Formation localities are closely spaced near the northern terminus of lower Chinle Group outcrops in the Lucero uplift. NMMNH L-248 is the lowest of these localities, and occurs in an intraformational conglomerate and sandstone that is sandwiched between slightly bentonitic, red, silty mudstones. Locality NMMNH L-249 appears to be similar, although in this case the red beds crop out above the McGaffey Member on Horse Mountain. Vertebrate localities NMMNH L-2279-81 occur in low exposures of red and purple mudstones stratigraphically higher than the McGaffey Member sandstone outcrop exposed in sec. 11, T5N, R5W.

TETRAPOD PALEONTOLOGY

The six tetrapod localities in the lower Chinle Group have produced a fauna consisting of the metoposaurid amphibian *Apachesaurus* sp., large metoposaurids that probably pertain to cf. *Buettneria*, the phytosaur *Rutiodon* sp., the aetosaurs *Desmatosuchus* sp., and cf. *Stagonolepis* sp., a probable theropod dinosaur, other, indeterminate reptiles, and numerous coprolites (Table 1). In the following sections I briefly describe the most significant of these specimens.

cf. *Apachesaurus* sp.

Apachesaurus is the smallest known metoposaurid amphibian and is identifiable from complete skulls or its elongate centra, but small clavicles and interclavicles cannot be diagnosed as readily (Hunt, 1993). Therefore, I tentatively assign NMMNH P-18392, a fragment of a small interclavicle collected from NMMNH L-3381 in the Bluewater Creek Formation, to *Apachesaurus* sp. Hunt et al. (1989, fig. 1-34.7D–E) identified NMMNH P-3657 from NMMNH L-249 as *Apachesaurus* (=*Anachisma* n. sp.). Material of *Apachesaurus* from the lower Chinle Group in the Lucero uplift is considerably rarer than material of larger metoposaurs, probably *Buettneria* (see below), as is typical in the lower Chinle Group (e.g., Hunt and Lucas, 1993b)

Metoposauridae indet.

Some of the most commonly encountered Upper Triassic vertebrate fossils found in the Lucero uplift are fragments of metoposaurid skulls, clavicles, and interclavicles. Almost all of this material is too large to represent *Apachesaurus*, but is not complete enough to determine whether it belongs to *Metoposaurus* or *Buettneria* (Hunt, 1993). This material was collected to present the best possible picture of the relative abundance of various taxa in the study area, but is not diagnostic below the family level. Hunt et al. (1989, fig. 1-34.7C) illustrated NMMNH P-3659, a skull fragment of a large metoposaur from NMMNH L-249.

TABLE 1. Tetrapod faunal list of the lower Chinle Group in the Lucero uplift

Unit	Taxa
San Pedro Arroyo Formation	*Desmatosuchus* sp.
Bluewater Creek Formation	cf. *Buettneria*
	Apachesaurus sp.
	Reptilia indet.
	Archosauria indet.
	Rutiodon sp.
	Parasuchidae indet.
	cf. *Stagonolepis* sp.
	?Theropoda indet.
	Vertebrate coprolites

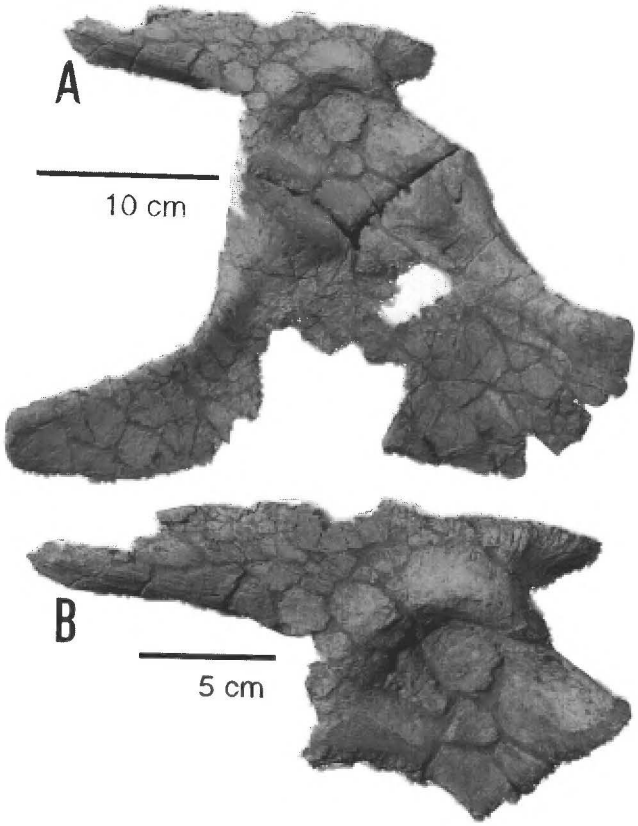

FIGURE 4. Right pelvis of the phytosaur *Rutiodon* sp., NMMNH P-28906, from NMMNH locality L-248 in the Bluewater Creek Formation in the Lucero uplift. A, entire pelvis in lateral view; B, close-up of right ilium in lateral view.

Rutiodon sp.

Isolated fossils of phytosaurs are probably the numerically most common Triassic tetrapod fossils in the Lucero uplift. Recently, the NMMNH collected several plaster jackets containing the right pelvis, an interclavicle, and numerous vertebrae and ribs of a phytosaur (NMMNH P-28906) from NMMNH locality L-248. This is the most complete Upper Triassic tetrapod collected from the uplift. To date, only the jacket with the right pelvis has been prepared (Fig. 4), but the preserved elements, particularly the ilium, are sufficient to diagnose this taxon as *Rutiodon* sp., *sensu* Ballew (1989). The following description highlights features that support this assignment.

The ilium is diagnostic to the genus level in phytosaurs (Camp, 1930; Hunt, 1994). Particular features of the ilium of P-28906 (Fig. 4) I note here are its relatively long proportions and the angulation of the pubic and ischiatic processes. The specimen is relatively long compared to its height, yielding a length:height ratio of 2:1 (Table 1). High length:height ratios are typical of the derived phytosaurs and preclude assignment to the primitive phytosaur *Paleorhinus* (Hunt, 1994). The ilium has distinct pubic and ischiatic processes, which form an angled ventral surface of the acetabular wall. Most other phytosaur ilia are flat across this junction, or else these two processes meet at an obtuse angle (Camp, 1930; Hunt, 1994; Long and Murry, 1995). The fact that these processes are so strongly developed that they meet at an approximate right angle supports assignment of this ilium to *Rutiodon* (=*Leptosuchus*), which it closely resembles.

I believe that the phytosaur taxonomy of Long and Murry (1995) is oversplit. Both they and Hunt (1994) separate specimens assigned by other workers to *Rutiodon gregorii* and place them in their own genus, *Smilosuchus* (Long and Murry, 1995). Measurements such as the ratio of the height of the ilium compared to the acetabular length (1.33:1) support assignment of P-28906 to "*Smilosuchus*" (Hunt, 1994). The ilium is considerably smaller than others assigned to *Smilosuchus* by Long and Murry (1995), but this is probably an artifact of ontogenetic development. The pelvis (Fig. 4A) is shown re-articulated, but the pubis and ischium were found rotated 90° and slightly dislocated (~30 cm) from the ilium, a fact that supports the hypothesis that NMMNH P-28906 represents a single, subadult individual. Until the taxonomy of phytosaurs is re-evaluated, I prefer to retain all specimens assigned to "*Smilosuchus*" in the genus *Rutiodon*, following Ballew (1989), and thus identify this specimen as *Rutiodon* sp. *Rutiodon*-grade phytosaurs, including "*Smilosuchus*," are known only from strata of well-constrained Adamanian (latest Carnian age), so the presence of *Rutiodon* indicates an Adamanian age for the Bluewater Creek Formation in the Lucero uplift (Figs. 2, 3).

Parasuchidae indet.

Aside from the ubiquitous fragmentary metoposaurid specimens, the most common identifiable Upper Triassic tetrapod fossils in the Lucero uplift are teeth, scutes, skull fragments, and vertebral centra of phytosaurs. Hunt et al. (1989, fig. 1-34.7I–J) illustrated a phytosaur rostrum fragment, NMMNH P-3656, from NMMNH L-249. A prolific site in the Bluewater Creek Formation, designated NMMNH localities L-3380-82, recently discovered by archaeologist R. Dello-Russo, has already produced a substantial number of phytosaur fossils after surface collecting, and appears to be very promising for future excavation. Particularly notable are several large vertebrae, which indicate another possible occurrence of *Rutiodon*.

Desmatosuchus sp.

Lucas and Heckert (1994, p. 249, fig. 9A–B) illustrated a partial dorsal paramedian scute of *Desmatosuchus* sp., NMMNH P-22297, from L-2810 in the San Pedro Arroyo Formation. This specimen, while not age diagnostic of a single land-vertebrate faunachron, does confirm the Late Triassic age of the San Pedro Arroyo Formation in the Lucero uplift. To date this is the only fossil identifiable to generic level from the San Pedro Arroyo Formation in the Lucero uplift.

cf. *Stagonolepis* sp.

Hunt et al. (1989, fig. 1.34-7F–H) identified some fragmentary osteoderms as scutes of the aetosaur *Stagonolepis* (=*Calyptosuchus*). Although I am nearly certain that this material pertains to *Stagonolepis*, it is exceedingly fragmentary. These scutes preserve only a generalized aetosaur ornamentation, which does eliminate many other genera from

TABLE 2. Measurements of the pelvis of NMMNH P-28906.

Characteristic (elements in **bold**)	Measurement
Ilium	
Total length	220 mm
Total blade length	210 mm
Length anterior iliac blade	26 mm
Length posterior iliac blade	107 mm
Total height	110 mm
Height acetabulum	84 mm
Length acetabulum	110 mm
Length pubic process	73 mm
Length ischiatic process	84 mm
Total length:height	2:1
Acetabulum length:height	1.33
Length posterior process:blade	0.51
Height/acetabular length	0.92
Pubis	
Length iliac process	78 mm
Greatest height	175 mm
Greatest length	158 mm
Obturator foramen (l x h)	33 x 25 mm
Ischium	
Length iliac process	60 mm
Greatest height	177 mm
Greatest length	210 mm
Length of posterior process	138 mm

consideration, but is not unambiguously that of *Stagonolepis*, so I can therefore only assign it to cf. *Stagonolepis* sp.

Theropoda? indet.

A single proximal right tibia, NMMNH P-18387, found at NMMNH L-3380, appears to be hollow, and is far too massive to pertain to a pterosaur. This element also preserves a weakly developed cnemial crest. The presence of a cnemial crest is a synapomorphy of the Dinosauria, and hollow limb bones and vertebrae occur in theropod dinosaurs (e.g., Novas, 1996). This bone may thus represent the tibia of a theropod dinosaur. It appears to be similar to the tibia of *Herrerasaurus* (Novas, 1993), but the hollow nature of this bone may be a preservational artifact, so it is referred to the Theropoda? here.

Trace fossils

To date, no Triassic tracks are known from the Lucero uplift, but occasional coprolites have been found. NMMNH P-18385 from NMMNH L-3380 is a typical Chinle vertebrate coprolite. Hunt et al. (1989, fig. 1-34.7K) illustrated another coprolite, NMMNH P-3660, from NMMNH L-249. Hunt et al. (1998) presented an ichnotaxonomy and biostratigraphy based on Chinle coprolites, but at this time I do not to assign these specimens to any of their coprolite ichnotaxa.

BIOSTRATIGRAPHY AND BIOCHRONOLOGY

The presence of phytosaurs and aetosaurs indicates a Late Triassic age for the Upper Triassic red beds of the Lucero uplift, as indicated by Case (1916). The only tetrapod fossils from the Chinle Group that provide further age control are the scutes assigned to cf. *Stagonolepis* sp., and to *Desmatosuchus* sp., and the partial skeleton of the phytosaur *Rutiodon* sp. Both *Stagonolepis* and *Rutiodon* are index taxa of the Adamanian land-vertebrate faunachron (Lucas and Hunt, 1993; Lucas 1998), and indicate a latest Carnian (approximately 225 Ma) age for the Bluewater Creek Formation in the Lucero uplift. The aetosaur *Desmatosuchus* sp. occurs in strata of Otischalkian to Revueltian (early Carnian to early-mid Norian) age, but is most abundant in strata of Adamanian age (Lucas, 1997, 1998). This, combined with the homotaxis of the San Pedro Arroyo and Bluewater Creek formations (Fig. 3), support an Adamanian age for that unit.

CONCLUSIONS

The Upper Triassic tetrapods collected from the Bluewater Creek Formation in the Lucero uplift represent a typical lower Chinle Group assemblage dominated by large metoposaurs and phytosaurs, with a smaller component of aetosaurs and other archosaurs. The isolated scutes of cf. *Stagonolepis* sp. and the pelvis of *Rutiodon* sp. collected from the Lucero uplift suggest an Adamanian (latest Carnian) age for the Bluewater Creek Formation in the Lucero uplift. The predominance of large metoposaurids and phytosaurs at the expense of other taxa is typical of many lower Chinle Group faunas. The abundance of large phytosaurs, including both *Rutiodon* and the very large phytosaur from L-3380, may be a preservational artifact, but may also have paleoecological implications. Identification of *Rutiodon* from the pelvic girdle shown in Figure 4 supports the hypothesis that phytosaurs can be identified by their ilia, which are diagnostic to at least the genus level (Hunt, 1994).

ACKNOWLEDGMENTS

Most of the Lucero uplift fauna was collected on lands owned by the Four Daughters Land and Cattle Company, and the NMMNH appreciates the generosity of Mr. Mike Mechenbier of that company, who donated these fossils to the NMMNH. The New Mexico Friends of Paleontology, especially K. Cockerill, G. Lindquist, H. Palm, W. Slade, L. Rinehart, B. Folks, and B. Jackson collected the specimens with the author and NMMNH preparator Pete Reser. NMFOP member and NMMNH volunteer Herb Palm expertly prepared the pelvis shown in Figure 4. Archaeologist R. Dello-Russo discovered localities L-3380-3382 and brought them to the attention of the NMMNH. This research was partly funded by a Vice President's Research Project and Travel Grant and several Student Research Allocation Committee Grants at the University of New Mexico as well as a grant from the Dinosaur Society. The NMMNH provided logistical support of all phases of this project. A preliminary version of this article appeared as a chapter in my M.S. thesis, and I appreciate the comments of my committee, M. Elrick, B. Kues, and S. G. Lucas. A later review by S. G. Lucas greatly improved this version of the manuscript

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APPENDIX—Systematic catalog of Upper Triassic tetrapod fossils from the Lucero uplift in the collections of the NMMNH

Specimens are listed taxonomically, then by NMMNH catalog number, with locality numbers provided in parentheses.

Metoposauridae indet.—Metoposaurid material found in the Lucero uplift includes the following: NMMNH P-3659, skull fragment (L-249); NMMNH P-17751, limb bone fragment (L-249); NMMNH P-17752, nine limb bone fragments (L-249); NMMNH P-17756, vertebra (L-249); NMMNH P-18386, centrum (L-3380); NMMNH P-18391, two skull fragments (L-3381); NMMNH P-18469, four skull fragments (L-3380); NMMNH P-18470, five jaw fragments (L-3380); NMMNH P-18471, numerous clavicle and interclavicle fragments (L-3380).

***Apachesaurus* sp.**—The only fossils from the Lucero uplift assigned to the small metoposaurid Apachesaurus are: NMMNH P-3657, skull fragment (L-249); NMMNH P-18392, interclavicle fragment (L-3381).

Reptilia indet.—This material includes the following: NMMNH P-3662, distal tibia fragment (L-249); NMMNH P-17753, two rib fragments (L-249); NMMNH P-17757, centrum (L-249); NMMNH P-18382, ten skull fragments (L-3380); NMMNH P-18383, ?sacral rib (L-3380); NMMNH P-18384, distal end of a limb element (L-3380); NMMNH L-18393, ?left transverse process (L-3381); NMMNH L-18394, distal end ?humerus (L-3381); NMMNH P-18468, girdle element (L-3381).

Archosauria indet.—This material includes: NMMNH P-3661, distal caudal vertebra (L-249); NMMNH P-17745, 13 skull fragments (L-249); NMMNH P-17756, five scute fragments (L-249); NMMNH P-17763, neural spine (L-249).

***Rutiodon* sp.**—Material assigned here to *Rutiodon* sp. is limited to NMMNH P-28906, a partial skeleton consisting of a right pelvis, the interclavicle, and numerous vertebrae and ribs, most of which remains unprepared at this time (L-248).

Parasuchidae indet.—Material assigned to the Parasuchidae that is otherwise indeterminate includes the following: NMMNH P-3656, rostrum fragment (L-249); NMMNH P-17739, scute (L-249); NMMNH P-17740, metapodial fragment (L-249); NMMNH P-17747, six vertebral fragments (L-249); NMMNH P-17748, five occipital condyle fragments (L-249); NMMNH P-17754, scute fragment (L-249); NMMNH P-17755, two tooth fragments (L-249); NMMNH P-18369, large cervical centrum (L-3380); NMMNH P-18370, large cervical centrum (L-3380); NMMNH P-18371, medium-sized dorsal centrum (L-3380); NMMNH P-18372, proximal left femur (L-3380); NMMNH P-18373, two large neural spines (L-3380); NMMNH P-18374, skull fragment (L-3380); NMMNH P-18375, highly unusual scute (L-3380); NMMNH P-18376, three teeth (L-3380); NMMNH P-18377, small cervical centrum (L-3380); NMMNH P-18388, five isolated teeth (L-3381); NMMNH P-18389, large scute (L-3381); NMMNH P-18390, small scute (L-3381); NMMNH P-18462, skull fragment (L-3381); NMMNH P-18463, three juvenile jaw fragments (L-3381); NMMNH P-18464, multiple isolated teeth (L-3381); NMMNH P-18465, numerous scutes (L-3381).

Parasuchidae indet.—Other material that is not diagnostic of the Parasuchidae but which was found in conjunction with abundant phytosaur material includes: NMMNH P-18466, three centra fragments (L-249); NMMNH P-18378, partial dorsal centrum (L-3380); NMMNH P-18379, partial dorsal centrum (L-3380); NMMNH P-18380, partial dorsal centrum (L-3380); NMMNH P-18381, ?sacral centrum (L-3380).

***Desmatosuchus* sp.**—This material is limited to: NMMNH P-22297, a partial paramedian scute (L-2810).

cf. *Stagonolepis* sp.—This material includes: NMMNH P-3658, partial left dorsal paramedian scute (L-249); NMMNH P-3663, two lateral scute fragments (L-249); NMMNH P-17749, dorsal paramedian and ?appendicular scute fragments (L-249); NMMNH P-18467, eight scute fragments (L-249).

Theropoda? indet.—This material is limited to: NMMNH P-18391, a proximal right tibia (L-3380).

Coprolites—Coprolites collected in the Lucero uplift include the following: NMMNH P-18461, eight vertebrate coprolites (L-248); NMMNH P-3660; vertebrate coprolite (L-248); NMMNH P-17758, coprolite (L-248); NMMNH P-18385, single vertebrate coprolite (L-3380); NMMNH P-18395, fourteen vertebrate coprolites (L-3381).

Ed Beaumont, Bill Hiss, and John Shomaker relaxing at Ghost Ranch during the 25th field conference in 1974. Besides being president of the Society that year, Hiss contributed seven articles to the guidebook (photograph courtesy of Ed Beaumont).